

**Independent Assessment of the Energy Savings,
Environmental Improvements and Water Conservation of
Emerging Non-Chemical Water Treatment Technologies**

By:

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Abstract:

This paper will discuss the results of a California Energy Commission Public Interest Energy Research (PIER) funded project to complete an independent assessment of the energy savings, environmental improvements and water conservation capabilities of the new and emerging non-chemical water treatment technologies. The project was completed by a team from California State University at Sacramento and included a technical review of several of the emerging technologies and a detailed assessment of two of the emerging non-chemical water treatment technologies. Clearwater Systems Corp. and VRTX Technologies, LLC produced the two technologies assessed. The research was focused on gathering information from industrial field customers who had purchased and installed these systems and had actual experience with the operational characteristics of these technologies ranging from several months to several years. The team completed a telephone survey with approximately 15 end user customers and made site visits to nine sites. Some limited independent water testing was also completed. The results of these phone surveys and site visits were consolidated and placed in an interim report. Even though only a small number of end user customers were actually surveyed or visited, the research indicated that several hundred systems have been successfully installed in California and throughout the United States. Both these emerging technologies provide non-chemical treatment for the make up water in cooling tower and evaporative condenser systems. All the information collected and results derived from this effort will be made available to the public later this year in the form of a PIER Technical Report. A Project Advisory Committee that included representatives from CalEPA, the Energy Commission PIER Program and local utilities supported this team.

Disclaimer:

This technical paper is a result of work sponsored by the California Energy Commission and does not necessarily represent the views of the Energy Commission, its employees or the State of California. This technical paper has not been approved or disapproved by the California Energy Commission nor has the Energy Commission passed upon the accuracy or adequacy of the information in this technical paper.

Introduction:

The California Energy Commission's Public Interest Energy Research (PIER) Program Industrial/Agricultural/Water (IAW) Team recently became aware of non-chemical water treatment technologies that provide potential energy efficiency improvements in industrial and commercial cooling tower and evaporative condenser applications. In addition to energy efficiency improvements, these technologies when applied provided "chemical free" water treatment of these systems. This "chemical free" environment eliminates the requirement to add treatment chemicals into the system water to control scaling, corrosion and biological agents that routinely form in these applications (these additive chemicals are considered toxic and environmentally undesirable). These technologies also report to provide increased water conservation and improve the quality of the water released into the ground water recovery systems at these industrial and agricultural applications.

The PIER IAW Team formed a Project Advisory Committee for this effort which included representatives from several PIER program areas (IAW, Buildings End-Use Energy Efficiency, and Energy-Related Environmental Research), California Environmental Protection Agency and several utilities from Northern California.). The primary purpose of this work effort was to perform an independent assessment of the capabilities and performance of emerging non-chemical water treatment technologies. This PAC was used to help review the progress of the effort and provide guidance on the completion of the research.

Background:

Makeup waters for cooling towers and evaporative condensers contain a wide range of impurities: dissolved solids, dissolved gasses, organic compounds, suspended solids and microorganisms. These impurities cause problems in cooling water systems as they increase in concentration as the water evaporates in the cooling process. The most common problems are scale, corrosion, and bacterial growth. To control these problems, industry has historically utilized traditional methods of chemical treatment.

A proper chemical treatment program needs to be adjusted, monitored and controlled. In practice this is difficult to accomplish as chemical treatment programs often consists of a series of compromises; and, a properly managed program requires constant adjustments due to changes in the system water as well as changes in make-up water. Typically, scale formation is inhibited by the use of acids and threshold inhibitors, including polymers, polyphosphates, phosphonates or a combination of these chemicals, along with managed cycles of concentration. Anodic, cathodic, or combinational corrosion inhibitors are added to slow down corrosion by forming a protective layer on metal surfaces. Zinc, copper, molybdates and other heavy metals are often added in formulations to increase the effectiveness of the chemical additives. Corrosive oxidizing and toxic non-oxidizing biocides are added to control the growth of microorganisms.

The use of some treatment chemicals can create additional problems and interfere with each other's performance. Acids are frequently used to control scale. Oxidizing biocides are used to control microorganisms. Low pH conditions enhance the effectiveness of biocides. Acids and biocides attack metal because of their oxidizing nature. To neutralize the corrosiveness of water, and to a degree to offset chemicals added for scale and bacterial control, corrosion inhibitors are added. Some corrosion and scale inhibitors may react with divalent cations in the system water to form pseudo scale. Phosphate based chemicals can be used by bacteria as a food source. Oxidizing biocides can breakdown certain types of scale/corrosion inhibitors; and, corrosion inhibitors require elevated pH levels in order to inhibit corrosion; yet, higher operating pH conditions adversely impact oxidizing biocides and their half-life.

Additionally, a growing number of water treatment chemicals are coming under even stricter laws relating to their use and handling. Added to this reality is the fact that the chemical costs, utility costs and training costs for the personnel who must handle the chemicals, store and dispose of the chemicals, are steadily increasing along with associated maintenance costs. And finally, many industrial companies have corporate mandates to lower water usage and reduce chemical usage corporate wide. These issues and the operational problems associated with traditional chemical treatment have collectively caused many cooling tower and condenser users to re-evaluate alternative, non-chemical methods.

During this effort, several emerging technologies that reported to provide non-chemical water treatment were reviewed. A criterion was developed to determine which technologies were to be surveyed and researched in more detail. The following criteria was used to select the emerging technologies to be research:

1. The emerging technology reported the ability to provide non-chemical water treatment for the make up water in cooling towers and evaporative condensers. Only technologies that reported treating scale, corrosion, and bacterial growth without the use of added chemicals were considered.
2. The emerging technology representative was able to provide a list of end use customers who had previously purchased and installed their technology at the end user facility. No PIER funding was used to purchase or test this technology in this effort.

3. The end use customers were willing to discuss the performance of their non-chemical treatment system with the research team and end user was willing to host a tour of their facility if requested

Based on these criteria, Clearwater Systems Corp. and VRTX Technologies, LLC were the two technologies assessed in this effort.

Technology Overview:

1. Description of Dolphin System™ Technology by Clearwater Systems Corp.

The Dolphin System™ is PULSED POWERED. It consists of two primary components:

- a) A high-frequency pulse generator (controller)
- b) A Coil-Pipe Assembly (Sized for full system flow)

The controller uses proprietary electronic circuitry to induce a high frequency, time varying electromagnetic field into the circulating water via the coil-pipe assembly. The coil-pipe assembly is essentially a section of PVC pipe outside of which a set of custom wound solenoid coils is fastened. Stainless steel pipe is used for boiler applications. There is no direct contact between the coils and the water. The coil-pipe assembly is applied to the full flow of the recirculating process water, and as result, water molecules are completely exposed to the pulsating electromagnetic field. It is preferably located between the discharge side of the condenser water circulation pump and the chiller. It may also be installed between the chiller and the cooling tower.

The Dolphin Pulsed Power System™, through the pulsed electromagnetic field, imparts a circumferential electric field in the bulk solution in opposition to the magnetic field, creating a complex electric field in the bulk solution. This affects the way minerals precipitate out of solution by altering the electrical charge of the colloidal particles so that they form “Colloidal nucleating powder” or crystals (at a microscopic level). The technique causes minerals to “CLUMP TOGETHER” (Nucleate) rather than depositing onto the equipment surfaces. The mineral crystals are subsequently carried off in the discharge blow-down. There is no velocity essential to this process, and the system is operable in all types of water chemistry without special construction or signal tuning. A full description of “Operating Principles: Method of Action” of Dolphin system is attached herewith with report.

Facts and figures of the Clearwater Systems Dolphin:

- Removes existing scale (depending on scale properties)
- Controls microbe (bacteria population) by limiting their ability to reproduce.
- Controls corrosion indirectly.
- Significant Water Savings compared to chemically treated tower.
- Financial savings
- Reduced maintenance
- More environmentally friendly
- It can treat the process waters of cooling towers, chiller systems, heat exchangers, direct evaporative air-coolers (“swamp coolers”), steam boilers, some hot water systems and fountains.

a) Scale Control:

The Dolphin System™ allows Calcium Carbonate and other dissolved minerals in the water to precipitate on suspended colloidal particles in bulk water rather than on the heat transfer surfaces. These colloids are available in the system bulk solution primarily from scrubbed in solids and secondarily those entering through make-up water. The unique spectrum and polarity of electromagnetic fields produced by pulsed power shifts the CaCO_3 equilibrium chemistry to favor formation of stable crystal nuclei in the bulk solution. Thus crystal growth and precipitation will occur in solution and accumulate as a loose powder instead of on a surface as a scale. (Details of Scale Control including picture is attached herewith in “Operating Principles: Method of Action- serial B”).

b) Bacteria Control;

With the Dolphin system, although the bacteria are not immediately killed, they are controlled. The Pulsing electromagnetic magnetic field from the Dolphin system generates a very low frequency, non-ionizing electromagnetic radiation. This pulse has the same shape and frequency as those generated by a pulsed-electric-field device developed by Maxwell Technologies and approved by the FDA for food Pasteurization. A Dolphin device uses a fraction of the energy that the Maxwell devices use on a per pulse basis. However, because cooling towers involve recirculation water, a Dolphin device on a cooling tower will “see” each bacterium many times before the bacterium exits the system. In a typical cooling tower setup, each bacterium will see over 5000 pulses, exposing the bacteria to over 50% on the total amount of radiation as with the Maxwell device. This exposure over a few hours does not have the same biological effect as a single dose obtained with the Maxwell device; however, there is recurring sub-lethal damage to the microorganisms. This damage is sufficient to inhibit reproduction but not sterilize the system. Some bacteria may recover in few days, but while they are being recirculated through the Dolphin they are inactive. (Details of Bacteria Control including picture is attached herewith in “Operating Principles: Method of Action- serial C”).

A second method of control is through the bulk-solution crystal growth described in the section on scale control. The formation of the crystals in the bulk solution will agglomerate bacteria and help inhibit their growth. The bacterial agglomerated in the process are removed from nutrient sources and have no path for waste product to exit. The result is similar to the flocculation process commonly applied for potable water supplies to clarify suspended solids from the raw water and in the process remove bacteria as a byproduct of the clarification. Essentially, the Dolphin System™ could be compared to this process while using a physical means of flocculation rather than a chemical means.

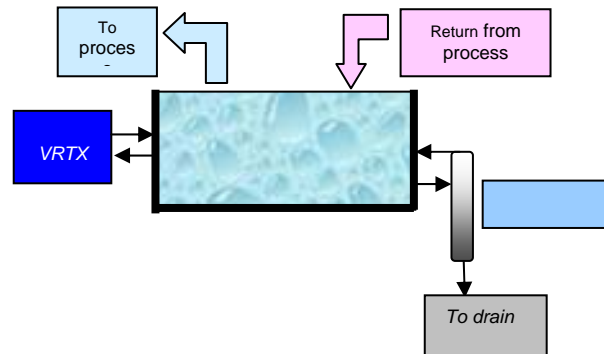
Field testing results offered by Clearwater Systems Corp has shown Heterotrophic Plate Counts (HPC by SMEWW pour plate method 9215B) of consistent planktonic control below 5,000 CFU/ml, with systems frequently operating below 1,000 CFU/ml. The Dolphin System™ has proven efficacy over biofilm, or slime layers, that exist in most cooling water systems. The benefit of biofilm eradication is the elimination of microbial influenced corrosion (MIC) which causes systems to develop metal failure in chiller tubes and piping systems. Such extensive biological control eliminates the addition of oxidizing biocides - further reducing the corrosion of systems.

c) Corrosion Control;

Corrosion inhibition with the Dolphin System is accomplished indirectly by maintaining sufficient cycles of concentration to force the system into and above the saturation point of calcium carbonate. Above the point of saturation, calcium carbonate provides excellent cathodic corrosion protection. Additionally, operation of the bulk solution in higher alkalinity and in pH ranging from pH 7.5 to pH 9 provides a rather benign water chemistry which is naturally less corrosive to metals used in cooling system construction. (Details of Scale Corrosion is attached herewith in “Operating Principles: Method of Action- serial D”).

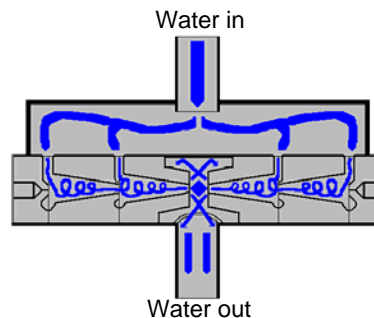
2. Description of operation of the VRTX technology

As illustrated below, the system is a side-stream treatment application. It includes two parts: a mechanical unit and a separation/filtration system. The separation/filtration system unit is used to remove the precipitated calcium carbonate and other suspended solids from the circulating cooling water.



The unit works primarily on the principals of Controlled Hydrodynamic Cavitation (CHC). Cavitation is the dynamic process of the formation, growth, and collapse of micro-sized bubbles in a fluid. When pressure falls below a critical value, cavities are formed in the liquid. When pressure increases, the cavity cannot sustain the surrounding pressure. Consequently, they collapse catastrophically. Studies have shown that when a liquid moves fast enough, gas bubbles will form and collapse creating a process called cavitation. Studies have indicated that in turbulent liquid flows, and notably at high velocity, hydrodynamic cavitation will occur.

The patented chamber, (depicted below), contained within the unit, consists of a pressure equalizing chamber and a cavitation chamber. Water is pumped from the sump into the pressure-equalizing chamber at a constant pre-determined pressure. The water is then channeled through opposing nozzles that impart a specific rotation and velocity to the water streams. The flow and rotation of the water streams creates a high vacuum, usually 27.5" Hg to 29.0" Hg.

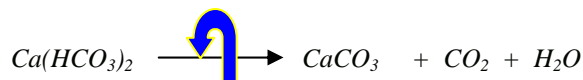


The water streams in the opposing nozzles rotate in opposite directions as they move forward at increasing velocity. Upon exiting from the nozzles, the water streams collide at the mid-point of the cavitation chamber. When the streams collide a region of high pressure is momentarily established causing vapor bubbles to collapse (implode) and the water chemistry to shift and chemical reactions to proceed. At the moment of bubble collapse an intensive shock wave and extremely high temperatures are generated. When this occurs, CO₂ and other dissolved gasses are released.

These combined effects are used by the technology to force the precipitation of calcium carbonate, control corrosion and eradicate microorganisms.

a) Scale Control:

By facilitating the precipitation of calcium carbonate, at lower temperatures, the mechanical unit continuously removes calcium carbonate, from the re-circulating cooling water. When water passes through the chamber, calcium carbonate is forced to precipitate out. The following equation describes the reaction that occurs within the chamber.



In the chamber the chemical equilibrium of the carbonate species is shifted, driving the above reaction to the right. As long as CO_2 is removed the equation tends to stay to the right. As a result, the soluble calcium bicarbonate converts into insoluble calcium carbonate (from solution to suspension) and, carbon dioxide gas is removed. The calcium carbonate colloids steadily grow and are easily removed from the water stream through the use of a filtration system.

Like any precipitation process, the formation of CaCO_3 in water is limited by the nucleation step. In order for the dissolved ions to react and form stable nuclei, extra energy is required to overcome the surface tension. This extra energy can be significantly reduced if nucleation takes place on existing surfaces such as equipment surfaces in cooling water systems or preferably on newly formed, pure colloidal CaCO_3 crystals.

With the effect of hydrodynamic cavitation, dissolved calcium and carbonate ions are forced to form within the chamber. The acceleration of nucleation via cavitation has been well documented and the small-sized CaCO_3 colloids act as growth sites for other dissolved ions. Continued crystal growth is thermodynamically favored over the formation of new nuclei (less required energy).

Normally, when cooling water travels to various hot spots, more dissolved calcium and bicarbonate tend to precipitate out because of the decrease in solubility causing scale build-up. Conversely, the mechanically treated water behaves differently. Instead of forming nuclei on the equipment surface, dissolved ions will redirect their growth on the newly formed colloids.

The Calcium Carbonate crystals continue to grow. As they grow in size, coagulation increases due to greater mass attraction. Crystal growth accelerates and the larger particles precipitate out and are removed by the filtration system.

b) Bacteria Control

The effectiveness of the unit in eradicating bacteria has been well documented. Several years of data has repeatedly shown nearly total eradication of E-Coli. Current testing has shown nearly identical results with various heterotropic bacteria. Field tests, independent laboratories and third party evaluations have confirmed these laboratory findings. Figures 3 and 4 summarized typical laboratory test results.

High vacuum, high pressure, high temperature, collision and mechanical sheer are believed to contribute to the killing of various microorganisms. Microscopic examination reveals that VRTX technology kills bacteria by physically rupturing the cell membrane. The exact mechanism is still under investigation; however, one or the combination of the following two actions may account for the major factors in eradicating bacteria:

- Dramatic changes in pressure and vacuum – When water passes through the chamber, it experiences dramatic changes in pressure/vacuum/pressure. The membrane wall of bacteria is permeable and fragile. Under such dramatic pressure changes over such a short period (seconds), it is believed that the cell membrane is ruptured. The direct impact of shear and collision forces created by the collision of water streams would also contribute to cell wall destruction. Once the

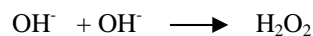
membrane is broken, vital liquid components inside the cell leak out, thereby causing the death of the bacteria.

- Hydrodynamic cavitation – When cavity bubbles collapse, an extremely high, localized temperature and pressure wave is momentarily created. The cell membrane of bacteria can easily be ruptured under these extreme conditions. Additionally, the cavitation process momentarily forms highly reactive oxidizing radicals and hydrogen peroxide, which are very effective in killing bacteria.

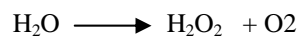
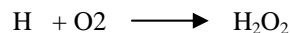
Under the action of cavitation, water molecules decompose into hydroxyl free radicals and hydrogen atoms:



The dissociation of water is thought to be produced by electrical discharges resulting from hydrodynamic cavitation or by thermal dissociation due to adiabatic compression of the collapsing bubbles (12). Hydroxyl radicals can combine to form hydrogen peroxide:



Hydrogen peroxide is also formed by the reaction between hydrogen atoms and dissolved oxygen in water:



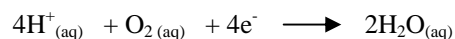
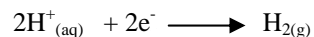
It is believed that both actions contribute to the eradication of microorganisms.

c) Corrosion Control:

Corrosion, triggered by the pH decrease of the process water, is a common problem for cooling tower maintenance and equipment life. Because the circulating water in a cooling water system contains oxygen, iron (or other metals) is oxidized when it comes in contact with the circulating water. The following equation illustrates this anodic reaction:



These electrons are then consumed by the hydrogen ion (H^+) in one of the following cathodic reactions:



Because the concentration of hydrogen ions is exponentially proportional to pH, a small decrease in pH will substantially increase the hydrogen concentration. This makes pH an important factor in controlling corrosion.

Other important factors that affect the rate of corrosion are the chemical composition of the water, the concentration of dissolved gases, flow rates, temperature, microorganisms, and type of metal exposed to the circulating water. Dissolved gases such as oxygen, carbon dioxide, sulfur dioxide, and sulfur trioxide build up in cooling circulating water as a result of continuous aeration. These gases which are absorbed into the cooling system water from the air (much like a scrubber) also contribute to the oxidation of metal as shown in the above reactions.

The technology minimizes corrosion reactions by reducing the corrosiveness of cooling circulating water. Eliminating corrosive chemicals, maintaining relatively high pH levels, and keeping the growth of microorganisms under control achieve this goal. Consequently, the corrosion reaction rates are reduced even at relatively high TDS levels.

Research Project Activities

The research team for this effort was selected from California State University at Sacramento. The research team completed the following activities in the completion of the project:

1. Assess several non-chemical treatment emerging techniques to determine if they met the criteria for this project.
2. Obtained a list of at least twenty end use customers from the two emerging technologies selected for further research.
3. Complete telephone surveys for a selected number of end user customers who had installed the technology.
4. Complete on site visits to several of the end users sites to gain better insight into the operation of the assessed technologies
5. Summarize the result of the entire effort in a final report for the PIER IAW Program.

Project Survey Results

The following is a summary report on the information gained from the telephone and site surveys. The same questions were presented to end users and a consolidated summary of their responses is listed below by technology:

The Dolphin System™ Technology by Clearwater Systems Corp survey results:

- 1) Type of Applications:

a) Cooling Tower	-	8
b) Evaporative Condenser	-	2
c) Boiler	-	0
d) Others	-	0

- 2) Number of systems installed at your site or location:

a) One	-	1
b) Two	-	0
c) Three	-	1
d) Four	-	3
e) More than Four	-	2

- 3) How long have you been using (Years) :

a) Less than a year	-	4
b) (1-2) yrs	-	5
c) (3- 4)Yrs	-	1
d) (4- 5)Yrs	-	0
e) (5-6) Yrs	-	0

- 4) Is the system still in use:

a) Yes	-	10
b) No	-	0

- 5) If not, what were the reasons for removing the system (s)? N/A
- a) Performance
 - b) Financial
 - c) Maintenance
 - d) Others
- 7) Are you satisfied with the overall performance of the system (s)?
- a) Yes - 10
 - b) No - 0
 - c) Any Comments - It is removing scale, lowering head pressure and most of all it is maintenance free.
- 8) Do you have any future plans to install additional systems at your current or any other company facilities?
- a) Yes - 8
 - b) No - 1 (Currently they don't have anymore facilities to install)
 - c) Don't know - 1
- 10) Did you use chemical water treatment in your system before?
- a) Yes - 10
 - b) No - 0
- 10) How long were you using chemical treatment prior to installation of system (s)?
- a) Less than 10 Yrs - 1
 - b) (11-20) Yrs - 3
 - c) (21-25) Yrs - 3
 - d) (26-30) Yrs - 1
 - e) > 30 Yrs - 2
- 11) Are you using chemical water treatment in other plant applications where this technology could be used as well:
- a) Yes - 8
 - b) No. - 2
- 12) How many sites or other company locations are you using chemical water treatment in other plant applications where this technology could be used as well? How many sites are currently using this technology?
- a) 65 - 1
 - b) 63 - 1
 - c) 10 - 1
 - d) 6 - 1
 - e) 2 - 1
 - f) 1 - 1
- 13) How did you learn about the _____ system?
- a) Sales call by vendor. - 6
 - b) Referred from others - 2
 - d) Trade show - 2
- 14) What is the main reason you decided to purchase the system?
- a) Economic - 1
 - b) Water saving and safety - 1
 - c) Environmental friendly and Economical - 4
 - d) Environmental friendly and remove scaling - 3
 - e) Reliability - 1

- 15) How long did it take you to decide to install the system?
 - a) No time - 2
 - b) (0 - 3) months - 2
 - c) (3 - 6) months - 5
 - d) > 6 months - 1

- 15) Does the system require routine maintenance, if so, how often?
 - a) Routine Maintenance not required - 8
 - b) Every week - 2

- 16) What type of routine maintenance does the system need?
 - a) Clean strainers - 1
 - b) Connection and visual check - 1

- 17) Do you regularly perform any type of water sample test on your system?
 - a) Yes - 9
 - b) No - 1

- 18) What water quality tests do you perform?
 - a) PH - 5
 - b) Conductivity - 8
 - c) Alkalinity - 3
 - d) Hardness - 3
 - e) Silica - 2
 - f) Corrosion Test - 1
 - g) Bacteria test - 2

- 19) How often do you perform this test (s)?
 - a) Every week - 3
 - b) Every two week - 3
 - c) Every month - 1
 - d) Quarterly - 2

- 20) How long do you keep the record of the test results?
 - a) Yes, forever - 8
 - b) One year - 1
 - c) No response - 1

- 21) Are you satisfied with the test results you have received to date?
 - a) Yes - 9
 - b) No. - 0
 - c) No response - 1

- 22) Have you observed any changes in scaling or befouling?
 - a) Yes - 8
 - b) No - 2

- 23) If you did observe any changes in scaling or biofouling, could you briefly describe what you saw.
 - a) Scale Control - 7
 - b) Less Biofouling - 1
 - c) Less Algae - 3
 - d) Bacteria Control - 1

- 24) Did you complete any economic analysis of the system (s) when you made the decision to install the system? If so, what was the estimated pay back time or other expected value provided by the new system?
- | | | |
|---------------|---|---|
| a) No | - | 3 |
| b) (0- 1) Yrs | - | 0 |
| b) (1-2) Yrs | - | 3 |
| c) (2-3) Yrs | - | 2 |
| d) > 3 Yrs | - | 2 |
- 25) Can you estimate the savings provided by the system(s) provided by the following:
- | | | |
|-------------------------------|---|---|
| a) Reduction of Chemical used | - | 9 |
| b) Water savings | - | 5 |
| c) Energy saved | - | 5 |
| d) less maintenance | - | 9 |
- 26) Can you quantify the total annual savings (in dollars) expected from the complete system?
- | | | |
|---------------|---|------------|
| a) \$(0-10) K | - | 7 |
| b) \$(20-50)k | - | 1 (\$ 48k) |
| c) No | - | 2 |
- 27) Have you recommended the system to others?
- | | | |
|--------|---|---|
| a) Yes | - | 9 |
| b) No | - | 1 |
- 28) Would you recommend the system to others?
- | | | |
|--------|---|----|
| a) Yes | - | 10 |
| b) No | - | 0 |
- 29) Do you have any additional comments or suggestions for our evaluation team?
- | | | |
|-------------------------------------|---|---|
| a) Satisfied with performance | - | 8 |
| b) Still observing, so far positive | - | 1 |
| c) No Comments | - | 1 |

VRTX Technology Survey Results:

- 1) Type of Applications:
- | | | |
|--------------------------|---|---|
| a) Cooling Tower | - | 5 |
| b) Evaporative Condenser | - | 3 |
| c) Boiler | - | 0 |
| d) Others | - | 0 |
- 2) Number of systems installed:
- | | | |
|----------|---|---|
| a) One | - | 1 |
| b) Two | - | 1 |
| c) Three | - | 4 |
| d) Four | - | 1 |
- 3) How long have you been using (Years):
- | | | |
|---------------|---|---|
| a) (1- 2) Yrs | - | 3 |
| b) (3- 4) Yrs | - | 2 |
| c) (4- 5) Yrs | - | 2 |
| d) (5-6) Yrs | - | 1 |

- 4) Is the system still in use:

a) Yes	-	7
b) No	-	0
- 5) If not, what were the reasons for removing the system (s)? N/A
- 6) Are you satisfied with the overall performance of the system (s)?

a) Yes	-	7
b) No	-	0
- 7) Do you have any future plans to install additional systems at your current or any other company facilities?

a) Yes	-	3
b) No	-	4
- 8) Did you use chemical water treatment in your system before?

a) Yes	-	6
b) No	-	1
- 9) How long were you using chemical treatment prior to installation of system (s)?

a) (20-25) Yrs	-	1
b) (25-30) Yrs	-	2
c) (30-35) Yrs	-	1
d) > 35 Yrs	-	2
- 10) Are you using chemical water treatment in other plant applications where this technology could be used as well:

a) Yes	-	3
b) No.	-	3
- 11) How many sites or other company locations are you using chemical water treatment in other plant applications where this technology could be used as well? How many sites are currently using this technology?

a) 4	-	1
b) 2	-	1
c) Zero	-	3
- 12) How did you learn about the system?

a) Sales call by vendor.	-	5
b) Referred from others	-	1
c) Trade show	-	1
- 13) What is the main reason you decided to purchase the system?

a) Economic	-	2
b) Water saving and safety	-	2
c) Environmental friendly and Economical	-	2
d) Easy to use	-	1
- 14) How long did it take you to decide to install the system?

a) No time	-	1
b) (0 - 3) months	-	2
c) (3 - 6) months	-	3
d) > 6 months	-	1

- 15) Does the system require routine maintenance, if so, how often?
- | | | |
|----------------------|---|---|
| a) Every day | - | 1 |
| b) Every week | - | 4 |
| c) Every month | - | 1 |
| d) Every three month | - | 1 |
- 16) What type of routine maintenance does the system need?
- | | | |
|-----------------------|---|---|
| a) Clean strainers | - | 5 |
| b) Power on | - | 1 |
| c) Change bag filters | - | 1 |
| d) Inspection | - | 1 |
- 17) Do you regularly perform any type of water sample test on your system?
- | | | |
|--------|---|---|
| a) Yes | - | 7 |
| b) No | - | 0 |
- 18) What water quality tests do you perform?
- | | | |
|---------------------------------------|---|---|
| a) PH ,Bacteria test and Conductivity | - | 1 |
| b) Standard water analysis | - | 4 |
| c) Standard analysis and PH | - | 1 |
| d) Water analysis and Bacteria test | - | 1 |
- 19) How often do you perform this test (s)?
- | | | |
|----------------|---|---|
| a) Every week | - | 2 |
| b) Every month | - | 5 |
- 20) How long do you keep the record of the test results? Forever.
- 21) Are you satisfied with the test results you have received to date?
- | | | |
|--------|---|---|
| a) Yes | - | 7 |
| b) No. | - | 0 |
- 22) Have you observed any changes in scaling or befouling?
- | | | |
|--------|---|---|
| a) Yes | - | 7 |
| b) No | - | 0 |
- 23) If you did observe any changes in scaling or biofouling, could you briefly describe what you saw.
- | | | |
|---|---|---|
| a) Scale, bacteria and corrosion control | - | 4 |
| b) Corrosion control and bacteria control | - | 1 |
| c) Less fouling | - | 2 |
- 24) Did you complete any economic analysis of the system (s) when you made the decision to install the system? If so, what was the estimated pay back time or other expected value provided by the new system?
- | | | |
|--------------|---|---|
| a) (0-1) Yrs | - | 1 |
| b) (1-2) Yrs | - | 2 |
| c) (2-3) Yrs | - | 2 |
| d) > 3 Yrs | - | 2 |
- 25) Can you estimate the savings provided by the system (s) provided by the following:
- | | | |
|-------------------------------|---|---|
| a) Reduction of Chemical used | - | 7 |
| b) Water savings | - | 7 |
| c) Energy saved | - | 7 |
| d) Less maintenance | - | 7 |

- 26) Can you quantify the total annual savings (in dollars) expected from the complete system?
- | | | | |
|----|---------------|---|---|
| a) | \$(0-50) K | - | 1 |
| b) | \$(50-100) K | - | 1 |
| c) | \$(100-150) K | - | 1 |
| d) | > \$150k | - | 2 |
- 27) Have you recommended the system to others?
- | | | | |
|----|-----|---|---|
| a) | Yes | - | 7 |
| b) | No | - | 0 |
- 28) Would you recommend the system to others?
- | | | | |
|----|-----|---|---|
| a) | Yes | - | 7 |
| b) | No | - | 0 |
- 29) Do you have any additional comments or suggestions for our evaluation team?
- | | | | |
|----|----------------------------|---|---|
| a) | Satisfied with performance | - | 5 |
| b) | No comments | - | 2 |

Key Take Ways from the Survey Efforts:

1. The project's qualitative survey found that respondents have had positive experiences with the alternative water treating technologies, indicating that growing market acceptance appears likely
2. As with any emerging technology, there are still many obstacles to obtaining complete commercial acceptance
 - Broader market acceptance
 - Increased number of fielded systems
 - Additional examples of clear economic paybacks
 - More published case studies by independent groups such as utilities, government agencies and others
3. Both technologies assessed are building a portfolio of case studies, independent reports and technical papers to aid in the market acceptance transition.
4. Both technologies are substantially increasing their installed base of operating systems

Next Steps

1. PIER final report will be published in next few months. The report will be available for public download on the Energy Commission PIER Web Site. The PIER Final Report will include more details on the energy savings, water savings and environmental benefits determine in this effort. This information will be reviewed by the Project Advisory Committee prior to being approved for publishing.
2. The Energy Commission and Cal EPA Staffs will complete a detailed assessment of the project results determine the recommended next steps.
 - a) Additional research and analysis.
 - b) Assessing the potential for consideration the technologies for energy savings, water savings and other government incentive programs.

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The PIER Program annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with RD&D organizations including individuals, businesses, utilities, and public or private research institutions.

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- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grant Program
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

Additional information on the PIER program can be obtained by visiting the California Energy Commission web site at <http://www.energy.ca.gov/pier/index.html>.

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